NEWTON'S APPLE®

Multimedia

Spinning

Waterskiing

Teacher's Guide

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Introduction

Welcome to the *Newton's Apple* Multimedia Collection™!

Drawing from material shown on public television's Emmy-award-winning science series, the multimedia collection covers a wide variety of topics in earth and space science, physical science, life science, and health. Each module of the *Newton's Apple Multimedia Collection* contains a CD-ROM, a printed Teacher's Guide, a video with two *Newton's Apple* ® segments and a scientist profile, and a tutorial video.

The Teacher's Guide provides three inquiry-based activities for each of the topics, background information, assessment, and a bibliography of additional resources.

The CD-ROM holds a wealth of information that you and your students can use to enhance science learning. Here's what you'll find on the CD-ROM:

- two full video segments from *Newton's Apple*
- additional visual resources for each of the *Newton's Apple* topics
- background information on each topic
- a video profile of a living scientist working in a field related to the *Newton's Apple* segments
- an Adobe Acrobat ® file containing the teacher's manual along with student reproducibles
- UGather ® and UPresent ® software that allows you and your students to create multimedia presentations
- QuickTime ® 3.0, QuickTime ® 3 Pro, and Adobe Acrobat® Reader 3.0 installers in case you need to update your current software

The *Newton's Apple Multimedia Collection* is designed to be used by a teacher guiding a class of students. Because the videos on the CD-ROM are intended to be integrated with your instruction, you may find it helpful to connect your computer to a projection system or a monitor that is large enough to be viewed by the entire class. We have included a videotape of the segments so that you can use a VCR if it is more convenient. Although the CD-ROM was designed for teachers, it can also be used by individuals or cooperative groups.

With the help of many classroom science teachers, the staff at *Newton's Apple* has developed a set of lessons, activities, and assessments for each video segment. The content and pedagogy conform with the National Science Education Standards and most state and local curriculum frameworks. This Teacher's Guide presents lessons using an inquiry-based approach.

If you are an experienced teacher, you will find material that will help you expand your instructional program. If you are new to inquiry-based instruction, you will find information that will help you develop successful instructional strategies, consistent with the National Science Education Standards. Whether you are new to inquiry-based instruction or have been using inquiry for years, this guide will help your students succeed in science.

WE SUPPORT THE NATIONAL SCIENCE EDUCATION STANDARDS

The *National Science Education Standards* published by the National Research Council in 1996 help us look at science education in a new light. Students are no longer merely passive receivers of information recorded on a textbook page or handed down by a teacher. The Standards call for students to become active participants in their own learning process, with teachers working as facilitators and coaches.

Newton's Apple's goal is to provide you with sound activities that will supplement your curriculum and help you integrate technology into your classroom. The activities have been field tested by a cross section of teachers from around the country. Some of the activities are more basic; other activities are more challenging. We don't expect that every teacher will use every activity. You choose the ones you need for your educational objectives.

Teacher's Guide

We suggest you take a few minutes to look through this Teacher's Guide to familiarize yourself with its features.

Each lesson follows the same format. The first page provides an overview of the activity, learning objectives, a list of materials, and a glossary of important terms. The next two pages present a lesson plan in three parts: ENGAGE, EXPLORE, and EVALUATE.

- ENGAGE presents discussion questions to get the students involved in the topic. Video clips from the *Newton's Apple* segment are integrated into this section of the lesson.
- EXPLORE gives you the information you need to facilitate the student activity.
- EVALUATE provides questions for the students to think about following the activity. Many of the activities in the collection are open-ended and provide excellent opportunities for performance assessment.

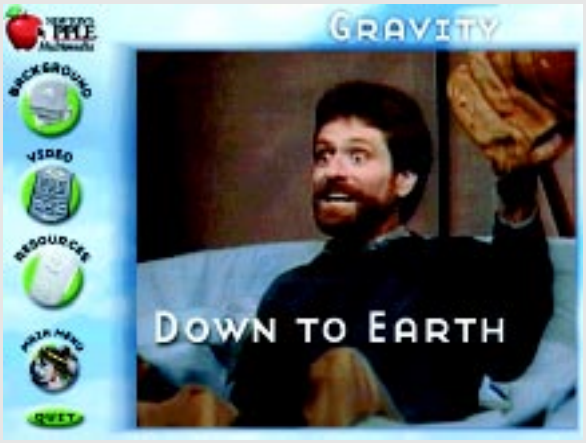
GUIDE ON THE SIDE and TRY THIS are features that provide classroom management tips for the activity and extension activities.

Using the CD-ROM

When you run the *Newton's Apple* CD-ROM, you will find a main menu screen that allows you to choose either of the two *Newton's Apple* topics or the scientist profile. Simply click on one of the pictures to bring up the menu for that topic.

Main Menu

Once you have chosen your topic, use the navigation buttons down the left side of the screen to choose the information you want to display.



Topic Menu

The Background button brings up a short essay that reviews the basic science concepts of the topic. This is the same essay that is in the Teacher's Guide.

Playing the Video

The Video button allows you to choose several different clips from the video segment. We have selected short video clips to complement active classroom discussions and promote independent thinking and inquiry. Each video begins with a short introduction to the subject that asks several questions. These introductory clips can spark discussion at the beginning of the lesson. The Teacher's Guide for each activity presents specific strategies that will help you engage your students before showing the video. Each of the individual clips are used with the lesson plans for the activities. The lesson plan identifies which clip to play with each activity.

Video Menu

Once you select a video and it loads, you'll see the first frame of the video segment. The video must be started with the arrow at the left end of the scroll bar. As you play the video, you can pause, reverse, or advance to any part of the video with the scroll bar. You can return to the Clips Menu by clicking on the Video button.

Multimedia Tools

The *Newton's Apple* staff has designed a product that is flexible, so that you can use it in many different ways. All of the video clips used in the program are available for you to use outside the program. You may combine them with other resources to create your own multimedia presentations. You will find all the video clips in folders on the CD-ROM. You may use these clips for classroom use only. They may not be repackaged and sold in any form.

You will also find a folder for UGather™ and UPresent™. These two pieces of software were developed by the University of Minnesota. They allow you to create and store multimedia presentations. All of the information for installing and using the software can be found in the folder. There is an Adobe Acrobat® file that allows you to read or print the entire user's manual for the software. We hope you will use these valuable tools to enhance your teaching. Students may also wish to use the software to create presentations or other projects for the class.

Technical Information

Refer to the notes on the CD-ROM case for information concerning system requirements. Directions for installing and running the program are also provided there.

Make sure you have the most current versions of QuickTime® and Adobe Acrobat® Reader installed on your hard drive. The installation programs for QuickTime 3, QuickTime Pro, and Acrobat Reader 3.0 can be found on the CD-ROM. Double-click on the icons and follow the instructions for installation. We recommend installing these applications before running the *Newton's Apple Multimedia* program.

Trouble Shooting

There are several Read-Me files on the CD-ROM. The information found there covers most of the problems that you might encounter while using the program.

Integrating Multimedia

We suggest that you have the CD-ROM loaded and the program running before class. Select the video and allow it to load. The video usually loads within a couple of seconds, but we recommend pre-loading it to save time.

All of the video segments are captioned in English. The captions appear in a box at the bottom of the video window. You can choose to play the clips in either English or Spanish by clicking one of the buttons at the bottom right of the screen. (You can also choose Spanish or English soundtracks for the scientist profile.)

The Resources button provides you with four additional resources. There are additional video clips, charts, graphs, slide shows, and graphics to help you teach the science content of the unit.

Resources Menu

The other navigation buttons on the left side of the window allow you to go back to the Main Menu or to exit the program.

NEWTON'S APPLE Multimedia

Spinning Teacher's Guide

It's Revolutionary

How do figure skaters spin around and around so fast? How do they suddenly increase their speed while spinning? What is the conservation of angular momentum and what does it have to do with a spinning object? What is gyroscopic action?

Themes and Concepts

- conservation of energy
- rotary motion
- angular momentum
- gyroscopic action
- stability

National Science Education Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard B: Students should develop an understanding of motions, forces, and transfer of energy.
Content Standard G: Students should develop an understanding of the nature of science.

Activities

1. ***Scott Hamilton's Spin—Approx. 20 min. prep; 65 min. class time***
Students learn what Scott Hamilton's arm and leg movements have to do with his ability to increase and decrease his spinning speed. Then students take a spin for themselves and learn about and experience the conservation of angular momentum.

2. ***Let's Roll—Approx. 15 min. prep; 60 min. class time***
Which will roll down a ramp faster—a can of chicken broth or a can of chicken noodle soup? What does the principle of angular momentum have to do with the contest? Students learn the role of distribution of mass in the conservation of angular momentum.

3. ***Gyroscopes—Approx. 20 min. prep; 45 min. class time***
How does a spinning object stabilize itself? What is gyroscopic action and why is it important? Students learn that angular momentum has direction as well as magnitude.

More Information

Internet

Newton's Apple
http://www.ktca.org/newtons
(The official *Newton's Apple* web site with information about the show and a searchable database of science ideas and activities.)

Science Learning Network
http://www.sln.org/
(Links to six prominent science museums across the country.)

Internet Search Words

angular momentum
gyroscopes
spinning
ice skating

Books and Articles

Doherty, Paul and Don Rathjen. *The Spinning Blackboard & Other Dynamic Experiments on Force and Motion*. New York: John Wiley & Sons, Inc., 1996. (One of the Exploratorium Science Snackbook Series, the book includes activities on angular momentum.)

Erlich, Robert. *Turning the World Inside Out and 174 Other Simple Physics Demonstrations*. Princeton: Princeton University Press, 1990. (Contains 19 relevant physics demonstrations on motion and angular momentum.)

Spinning

Walker, Jearl. Roundabout: *The Physics of Rotation in the Everyday World.* A Scientific American Reader. New York: W.H. Freeman and Co., 1985. (Amusement park rides, ballet, and martial arts are among topics viewed from the perspective of physics.)

Zubrowski, Bernie. *Tops: Building and Experimenting With Spinning Toys.* New York: William Morrow and Co., 1989. (An activity book from the Boston Children's Museum with carefully designed demonstrations involving spinning.)

Community Resources

Ballet, gymnastics, or figure skating instructors

Local college or university physics departments

Background

Rotational motion may be a challenging physics concept to think about, yet skaters and gymnasts, without knowledge about the principles of angular momentum and gyroscopic stability, apply these principles magnificently through their body movements.

The physics of rotational motion is often best understood by analogy to linear motion. Think about a toy dump truck rolling along at a steady speed. Now imagine that you drop a roll of candy into the truck's bed. The truck immediately slows down. Drop a heavier object into the truck's bed and it slows even more. What's going on?

The total mass of the truck increases when you add the mass of the candy to it. Its forward momentum—the product of the mass times its speed—must stay the same, according to the "law of conservation of momentum." The only way the momentum can stay the same is for the speed to decrease. So, the truck slows down. Friction will eventually rob the truck of its energy and the momentum will decline to zero.

Now imagine a similar experiment with a freely spinning turntable and a piece of soft clay. You would notice a similar effect, but with an important difference. If you drop the clay near the center, the turntable will barely change its rotational speed; if you drop the clay near the edge, however, the turntable will slow considerably. The heavier the clay or the farther from the center it is placed, the bigger the change. *Now* what's going on? Where the clay is dropped is important because angular momentum depends not only on mass and speed, but also on the distance between the mass and the axis of rotation. To figure out the value, or magnitude, of angular momentum you need to understand a physical quantity known as "moment of inertia." The farther the mass is from the axis of rotation, the greater the "moment of inertia." So angular momentum is basically the rotational equivalent of linear momentum.

To understand a skater's spin, what you really need to know is that the magnitude of the skater's angular momentum remains the same throughout the spin. When a skater brings her arms in tight, the moment of inertia goes down, so the speed of the spin has to increase. When the skater stretches her arms out, the moment of inertia goes up, so the speed goes down. And what does all of this have to do with a gyroscope? The angular momentum of a spinning object not only keeps it spinning, it tends to keep the axis fixed in the same position. That's why a spinning top tends to stay upright and why it's not *too* hard to spin a basketball on one finger.

Does all this make your head spin? It's not so hard if you remember that the momentum of a moving body is conserved that is it stays the same. It's the law!

Video & Stills

Video Segments

Introduction

25:05 to 25:34—Dave Huddleston wonders how skaters can keep spinning when he finds it hard to spin a basketball on a finger.

Video Clip 1

25:41 to 28:02—Olympic Gold Medalist Scott Hamilton demonstrates how angular momentum keeps him spinning. (2 min. 21 sec.)

Video Clip 2

28:03 to 28:23—Scott Hamilton shows how he can change his spinning speed by changing the position of his arms and leg. (20 sec.)

Video Clip 3

28:23 to 29:54—Scott Hamilton skates his way to a winning performance with the help of angular momentum. (1 min. 31 sec.)

Additional Resources

Button A

Video: Newton's Apple Science Try-It. Students explore gyroscopic action with an old LP and some string.

Button B

Video: A member of the Harlem Globetrotters shows how gyroscopic action helps him score with fans.

Button C

Video: Newton's host David Heil demonstrates how a spinning bike wheel is like a gyroscope.

Button D

Illustration: Graphic of the inner ear, the part of the body that helps us maintain balance

Unit Assessment Answer Key

The Unit assessment on the following page covers the basic concepts presented in the video segment and the Background on the Unit Theme section in this guide. The assessment does not require completing all of the activities. However, students should view the complete *Newton's Apple* video before doing this assessment. The Unit Assessment may be used as a pre- or post-test. There is additional assessment at the end of each activity.

Think about it

1. He extends them, holding them straight out from his body, because the further the mass is from the center of rotation, the slower an object will spin.
2. He brings them in as close to his body as possible, because it increases the amount of mass near the rotational axis.
3. Divers and gymnasts both keep their legs and arms tucked in closely to their bodies when they want to do a somersault in the air. Other sports may be mentioned as well.
4. Theoretically, the earth would spin faster because its mass would not extend as far away from its rotational axis.
5. A meter stick is easier to balance than a pencil because the mass of the meter stick is spread out over a greater distance from its rotational axis. A pencil is smaller, therefore its mass is not distributed very far from its rotational axis.

What would you say?

6. a 7. b 8. d 9. b 10. c

NEWTON'S APPLE Multimedia

Unit Assessment

What do you know about Spinning?

Write the answers in your journal or on a separate piece of paper.

Think about it

1. What does Scott Hamilton do with his arms and leg when he wants to spin slowly? Why?

2. What does Scott do with his arms and leg when he wants to spin quickly? Why?

3. Give an example of another sport or activity in which the principle of angular momentum is important.

4. Theoretically, how would the spinning motion of Earth change if all mountains were leveled? Why?

5. Which is easier to balance on your finger—a meter stick or a pencil? Why?

What would you say?

6. If two swings were given a push of equal force, a swing with long ropes will swing back and forth more slowly around its axis than a swing with short ropes because—
   a. the swing with long ropes is farther from the rotational axis.
   b. gravity pulls more strongly on longer objects.
   c. angular momentum always works better with short ropes.
   d. the long swing covers more distance.

7. Momentum—
   a. means that an object will always continue to move for several moments.
   b. is the tendency for an object to continue to move in the direction it is going.
   c. is the tendency for an object to slow down.
   d. is the tendency for an object to speed up.

8. Which of the following is not an example of the conservation of angular momentum?
   a. a child turning a somersault
   b. an old tire rolling down a hill
   c. a swinging pendulum
   d. a ball bouncing up and down

9. If more of the mass or weight of a rotating object is near its axis—
   a. the object will tend to wobble.
   b. the object will tend to spin more quickly than if the mass is farther from the axis.
   c. there will be no effect.
   d. the object will spin more slowly than if the mass is farther away from the axis.

10. A solid disk and a hoop with equal mass and diameter are dropped from one meter onto the top of a ramp. Which of the following is true?
    a. The objects hit the ramp at the same time, and they reach the bottom of the ramp at the same time.
    b. The objects hit the ramp at the same time, but the hoop reaches the bottom of the ramp first.
    c. The objects hit the ramp at the same time, but the disk reaches the bottom of the ramp first.
    d. The hoop beats the disk to the ramp and to the bottom of the ramp.

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Activity 1

Scott Hamilton's Spin

How do figure skaters, gymnasts, ballet dancers, and divers increase their speed during spinning or rotating maneuvers? What physics principles are they applying when they tuck in their arms and legs close to their body?

Getting Ready

Overview

Students learn what physics has to do with figure skater Scott Hamilton's ability to change his speed as he spins around and around on his skates. Students observe and study Scott's spin. Then they take a spin on a piano stool to experience the conservation of angular momentum.

Objectives

After completing this activity, students will be able to—

- explain how figure skaters use body movements to change their speed while spinning
- discuss how rotational speed depends on the distribution of mass around an axis of rotation

Time Needed

Preparation: approx. 20 min.
Classroom: approx. 65 min.

Materials

For the teacher:

- round, glass casserole cover with a flat stem handle
- plastic drinking straw
- two 300-gram lumps of modeling clay

For each group of students:

- piano stool that will spin but not pivot out of the sleeve in which it is set (a rotating turntable will work equally well)
- two exercise weights of equal size—about 1-2 kilo each
- notebooks or sketch pads and pens and pencils

Important Terms

angular momentum — The tendency of a rotating object to continue to spin.

axis — A straight line around which an object rotates or revolves.

rotation — The spinning motion that takes place when an object rotates around an axis that runs through the center of its mass.

Spinning

Video Clip 1
25:41 to 28:02—Olympic Gold Medalist Scott Hamilton demonstrates how angular momentum keeps him spinning. (2 min. 21 sec.)

Video Clip 2
28:03 to 28:23—Scott Hamilton shows how he can change his spinning speed by changing the position of his arms and leg. (20 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction listed in the Video Menu on the CD-ROM [25:05 to 25:34]. Find out what students think about the topic. As a class, discuss the questions posed by Dave Huddleston.
- For the first demonstration, the glass casserole cover must be round. Any other shape may wobble as it spins. You might want to experiment with the height from which the clay dumbbell is dropped on the spinning casserole cover. The two balls of the dumbbell should hit the casserole cover at the same time. Try dropping the dumbbell as close to the spinning cover as possible.
- After all of the students have had a chance to spin on the piano stool or turn table, solicit suggestions on ways the activity might be altered. Then have students implement their suggestions and describe the results. For example, a student may wonder about the effect of leaning forward on the stool, or tucking the knees under the chin.
- Review any classroom safety rules before students spin on the stool. Students should be cautioned not to spin too fast.
- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on spinning after completing the activity.

Here's How

Preparation
- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for the activity.
- Make a copy of Activity Sheet 1 for each student.
- Review the Background information on page 8.

Engage (Approx. 20 min.)

Before class, assemble together two large balls of clay, a drinking straw, and a round, glass casserole cover with a flat stem handle. Insert each end of the straw into one of the balls of clay, forming a dumbbell almost the diameter of the casserole cover. The combined weight of the clay balls should be about the same as the casserole cover. Flatten the clay balls slightly so they will not roll.

Begin by talking with students about figure skating. Have they seen Olympic events on TV? Have they ever seen a live performance? Have they ever seen a skater spin? Have they noticed how skaters spin faster and faster? How do they do that? Accept all answers.

Begin the class with a demonstration of the conservation of angular momentum. Have a student spin the round casserole cover upside down on a table. As the cover is spinning, drop the clay dumbbell onto the center of it from a height of about 5 cm so that the balls of clay land at the same time. Ask students what they observed. (The spinning slowed.)

Next, push the ends of the straw deep into the clay balls so that the balls come into contact with each other. Have a student spin the casserole cover again, and drop the clay onto the middle of the cover once more from the same height. Ask students for their observations. (The cover slowed again but not as much as when the long dumbbell was dropped.) Ask students what accounts for the difference. Accept all suggestions.

Show Video Clip 1 [25:41 to 28:02]. Tell students to observe Scott Hamilton's spinning action, and ask them to explain how it is similar to the demonstration with the clay dumbbells. (When the dumbbells are moved closer to the axis of rotation, the spinning speed increases.)

Activity 1

Explore (Approx. 45 min.)

Tell students that they are going to analyze Scott Hamilton's motions as he spins on his ice skates, and then they are going to simulate the spinning that Scott Hamilton does so well.

Have students work in small groups with several classmates. Show Video Clip 2 [28:03 to 28:23], in which Scott changes his spinning speed by moving his arms and leg. Allow students to view the video clip slowly or frame by frame so they can make a close examination of Scott's motions. The slider bar and arrows at the bottom of the video window on the CD-ROM allow you to play the video forward or backward, frame-by-frame. Have students sketch Scott Hamilton's arm movements while he is increasing his spinning speed. Make sure they understand the connection between the spinning speeds and the position of Scott Hamilton's arms. What does Scott do to speed up his spin? (Students should notice that he brings his limbs in close to his body, around his body's rotational axis.)

Tell students that they are going to have the chance to spin on their own. They will take turns sitting on a rotating stool or turntable and experience the effect of extending and retracting their arms on their rotating speed.

Each group should come up with a way of testing their observations and ideas of how Scott Hamilton increased the speed of his spin.

Students can use weights or other heavy objects to test their ideas about spinning. They should record their observations and come to some conclusions that they can share with the class.

Discuss students' conclusions as a class. Discuss how the distribution of mass around an axis affects the speed of the rotation. The further the mass is distributed from the rotational axis, the slower the spin.

Evaluate

1. Describe what a skater would have to do to achieve a very fast spin. (The skater would have to begin the spin with her arms and one leg extended from her body. After beginning the spinning motion, the skater would have to bring her arms and leg in close to her body. The harder the push that begins the spin, the faster the final spin will be.)

2. A space station has begun to spin out of control. Where should the astronauts go in the craft to try to slow the spinning? (They should all be as far from the rotational axis as possible.)

3. What is the best body position for a diver who has to flip over twice before reaching the water? Why? (Arms and legs tucked in as close as possible to the body. This position brings the body mass close to the rotational axis, making it possible to turn somersaults in the air rapidly and before hitting the water.)

Try This

Make identical tops from round margarine tubs or similar containers and a pencil or skewer. On one of the tops, add a lump of clay around the axis. Add the same amount of clay to the outer edge of the other top. Spin the tops and record your observations.

Set in motion a long pendulum and a short pendulum. Why does one swing faster than the other?

SCOTT HAMILTON'S SPIN

Activity Sheet 1

NAME _____ CLASS PERIOD _____

WHAT YOU'RE GOING TO DO

You're going to observe and simulate the spinning that Scott Hamilton does on figure skates.

HOW DO IT

1. Work with a partner or small group. View Video Clip 2 on the CD-ROM, in which Scott Hamilton changes his spinning speed.

2. Make a rough sketch of Scott's body position as his spinning speed goes from slow to medium to fast. If necessary, view the segment frame by frame to make a close examination of Scott Hamilton's motions. You can use the slider bar and arrows at the bottom of the video window to play the video forward and backward. Observe his spin. Figure out what he does to increase the speed of his spin.

3. With your group, come up with a way of testing your theory about how skaters increase the speed of their spin. You can use the weights and piano stool that your teacher has provided or come up with your own method. Record your observations.

RECORDING YOUR DATA

In your science journal, sketch Scott Hamilton's spin. Draw sketches of his body position at slow, medium, and fast speeds. Write a couple sentences that describes how Scott does it.

Write down the observations you made of your experiences spinning on a piano stool.

You may want to record the revolutions per minute (rpm) that are produced by different body positions.

WHAT DID YOU FIND OUT?

From the video and from your experience on a piano stool or turntable, what is the relationship between speed and the skater's body position.

Did you find that your experience on the piano stool was similar to how Scott Hamilton increased the speed of his spin? Explain.

Are there other variations in body movement that affect your spinning speed? What did you try?

How did your results compare to those of other groups? Discuss any differences and why they may have occurred.

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Activity 2

Let's Roll

What is an axis of a spinning object? How does the distribution of the mass around the axis affect the rotational speed of the object? How do athletes and others use this physics principle.

Getting Ready

Overview

Students investigate the effect of the distribution of mass on rotation. With the help of a ramp, canned food, and other rolling objects, the students discover that the relationship between the axis and location of mass can affect how an object rotates.

Objectives

After completing this activity, students will be able to—

- explain the role of the distribution of mass and rotation
- accurately predict which objects will roll faster than others

Time Needed

Preparation: Approx. 15 min.
Classroom: Approx. 60 min.

Materials

For the teacher:

- can of chick broth and a can of chicken noodle-and-vegetable soup
- 2 transparent, half-liter plastic bottles
- ramp

For each team of students:

- ramp for rolling objects
- stopwatch
- three round cookie tins or coffee cans of the same size and shape with metal lids
- 16 large, heavy washers
- duct tape

Important Terms

angular momentum — The tendency of a rotating object to continue to spin.

axis — A straight line around which an object rotates or revolves.

rotation — The spinning motion that takes place when an object rotates around an axis that runs through the center of its mass.

Spinning

Here's How

Video Clip 3
28:23 to 29:54—Scott Hamilton skates his way to a winning performance with the help of angular momentum. (1 min. 31 sec.)

Preparation
- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Construct a ramp for rolling objects. The ramp should be at least 2 meters in length and inclined between 10 and 20 degrees. Plywood or fiberboard work well.
- Make a copy of Activity Sheet 2 for each student.
- Review the Background information on page 8.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction listed in the Video Menu on the CD-ROM [25:05 to 25:34]. Find out what students think about the topic. As a class, discuss the questions posed by Dave Huddleston.
- For the demonstration, another clear broth and a soup that contains noodles or vegetables may be substituted for the chicken broth and chicken vegetable soup. The cans should be the same size and weight.
- For the activity, it is important that all students have identical cans and other materials to work with so that students are working with the same variables for the competition.
- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on spinning after completing the activity.

Engage (Approx. 15 min.)

Begin by asking students which they think is faster—chicken broth or chicken vegetable soup. Explain that you are going to roll cans of these soups down a ramp. Take a poll and get students to explain why they chose one soup over the other. Accept all suggestions.

Begin the race down a ramp. Get students reactions and reasons why they think the chicken broth won the race. (The vegetable content moves away from the axis of rotation. The can of broth, on the other hand, has more of its mass distributed near its center, so it spins faster. Also, when the vegetable soup can is on its side, the vegetables can create higher inertia, so the can can't get rolling as quickly.)

Try the race again using two transparent, half-liter plastic bottles. Fill both of the bottles with water, and in one of the bottles add six or seven coins. Ask students which will win a race down a ramp. (The bottle that contains only water.) Why? (Like the can of vegetable soup, the coins move away from the rotational axis. The closer the mass is located to the center of rotation, the faster the object will spin.)

Remind the students that according to Galileo, objects fall at a constant rate regardless of their weight, so a heavy bottle has no advantage over a lighter one. Ask the students what might account for the discrepancy in the ramp rolling activity, in which the heavier bottle of water is slower. Show Video Clip 3 [28:23 to 29:54]. Ask the students how the rolling object activity is related to the video segment in which Scott Hamilton spins and does a back flip on the ice. (Both revolve around an axis.)

Activity 2

Explore (Approx. 45 min.)

Tell students they are going to use metal containers of equal size and weight and roll them down a ramp to determine the effect of the distribution of mass on a rolling object. Their objective is to build a container that will roll faster than those of other groups.

Have students work in small groups. Each group should have 16 washers, a coffee can (or cookie tin) and lid, and duct tape for attaching the washers. Students should experiment with the materials and attach washers to the can in different configurations. They should figure out which configuration works the best and then enter their rolling can into the competition.

After groups have had time to experiment and test their entries, hold a competition to find which group has the fastest rolling can.

After the competition discuss the winning design(s) and why they worked the best. (A design that has the washers attached at the axis on the bottom and lid of the can will work best.)

Evaluate

1. Which is likely to lose a race down a ramp—an empty, 2-lb coffee tin or an empty, 2-lb coffee tin with an empty 1-lb coffee tin secured in the center of it? (The empty 2-lb coffee tin with nothing inside of it.) Why? (Because its mass is distributed farthest from its axis.)

2. Two tires of equal size are rolling down a hill. One is on a wheel and the other has no wheel. Which reaches the bottom of the hill more quickly? Why? (The tire on the wheel. It has more mass closer to the axis of rotation.)

3. Explain how the principle of angular momentum applies to pendulums. (A pendulum can be considered an object with a rotational axis. The shorter the pendulum, the more mass is distributed near its axis, the closer its mass is to the axis of rotation, and the faster it swings back and forth.)

Try This

Make two batons of equal size and weight, but with different distributions of mass. Use two 50-cm dowels about a centimeter in diameter. On one of the dowels attach 30 washers in the center; on the other, attach 15 washers at each of the ends. Twirl the batons and note the difference you feel between the two. What is the difference?

Balance a meter stick vertically on the end of a finger or your hand. Try it with a lump of modeling clay on it. Put the lump of clay at the bottom of the stick near your hand. Then try it again near the top. Which is easier to balance? Why? How does the principle of distribution of mass affect your ability to balance it?

NEWTON'S APPLE Multimedia

LET'S ROLL

Activity Sheet 2

NAME _____ CLASS PERIOD _____

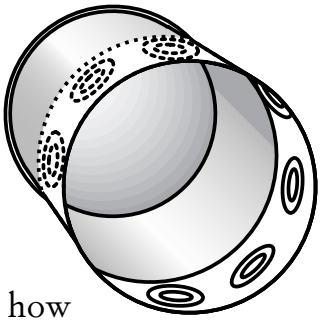
WHAT YOU'RE GOING TO DO

You'll modify a can to roll faster by attaching washers to it to change the distribution of mass. You'll then compete against other groups to see which group makes the fastest can.

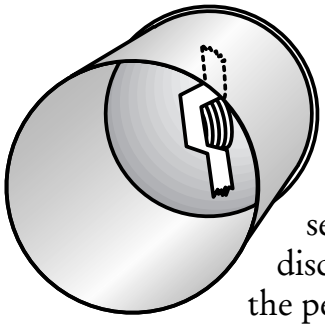
HOW TO DO IT

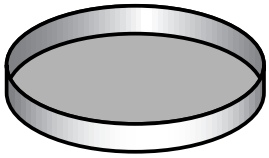
1. Work with your group. Your goal is to fasten washers to your can in a way that makes it roll fastest.

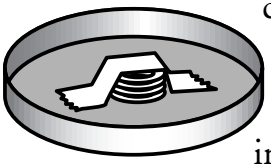
2. You must use all the washers. You may position the washers on the inside or outside of the can.



3. Before you begin, discuss as a group your ideas for how to position the washers. Think about what you know about how rotation is affected by the distribution of mass.







4. Attach washers to the can with tape. Try attaching the washers in several different locations. Test how the different locations affect the speed of the can going down the ramp. Weigh the two cans. Are they equal or not?

5. Race your fastest can design against other groups' designs.

6. After a winner has been selected from all the groups, discuss what factors affected the performance and speed of the can.

RECORDING YOUR DATA

In your science journal, record information about this activity. Summarize the discussion your group had about where the washers should be located. Draw a sketch or describe the different ways you attached the washers. Write down your observations of how the can rolled each time.

WHAT DID YOU FIND OUT?

Which of your can designs was the fastest? What reasons can you come up with to explain why it was the fastest?

How did your group decided where to place the washers? How did the placement of the washers relate to a skater spinning?

Discuss what factors might account for one group's can being faster than any other in the class.

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Activity 3

Gyroscopes

What is the secret of balancing a basketball on a fingertip? What is necessary for a football to hit its target? What is a gyroscope? What does gyroscopic action have to do with the conservation of angular momentum?

Getting Ready

Overview

Students learn about the tendency of a rotating object to maintain a constant spin axis—gyroscopic action. Students observe the action in various objects, and then they experience gyroscopic action in a spinning phonograph record and a spinning bicycle wheel.

Objectives

After completing this activity, students will be able to—

- explain how angular momentum has direction as well as magnitude
- explain why a gyroscope resists changes in direction of its axis
- discuss gyroscopic stability

Time Needed

Preparation: Approx. 20 min.
Classroom: Approx. 45 min.

Materials

For the teacher:

- toy top
- small rubber football
- toy gyroscope
- bicycle wheel with hub and handles to hold the hub

Each team of students needs:

- old 33 rpm record
- round toothpick
- piece of string about a meter long

Important Terms

gyroscope — A disk on a shaft, which rotates on a support frame. The direction of the disk's spinning axis will not change if the disk is spinning fast enough.

gyroscopic action — The tendency of a rotating object to maintain a constant spin axis.

Spinning

Here's How

Resource Button B
Video: A member of the Harlem Globetrotters shows how gyroscopic action helps him score with fans.

Resource Button C
Video: Newton's host David Heil demonstrates how a spinning bike wheel is like a gyroscope.

Preparation
- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 3 for each student.
- Review the information in the Background on page 8.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction listed in the Video Menu on the CD-ROM [25:05 to 25:34]. Find out what students think about the topic. As a class, discuss the questions posed by Dave Huddleston.
- Students should understand that, while gyroscopic action accounts for the tendency for a bicycle wheel to roll without falling over, it does not account for the ability of a person to keep a bicycle balanced when it moves. The rider's ability to balance or to keep his or her center of mass over the bicycle contributes to the bike's overall stability.
- If time allows, you may wish to have students view the entire Newton's Apple video segment on spinning after completing the activity.

Engage (Approx. 20 min.)

Begin with a demonstration of a spinning toy top. Set a top spinning on a desk, and ask students why it does not fall over. Accept all answers. Ask students if they can think of an example of a similar spinning object whose axis does not change.

Toss a small rubber football into the air with a spinning motion. Ask students what the similarity is between the football and the top. Toss the football to a student in a way so that it does not spin. Ask students why the spin is important to football players. (The spin keeps the football on track to its target; the axis of a rotating object does not change direction.)

Spin the top on the desk again. Let the top spin until it begins to wobble. Ask students why the axis of the top begins to change directions. (Because the spinning became too slow.) Tell students that this is called "precession"—the direction of the axis of a spinning object changes. Show the short video clip at Resource Button B on the CD-ROM. Ask students how the spinning basketball is similar to a top. (It is revolving around its axis.)

Set a bicycle wheel on its tire, and ask students what they think will happen if you let go of it. (It will fall over.) Ask students if it will fall over if you roll it. (It tends to stay up as long as it is rolling.) Ask students what will happen if you tap the wheel gently on one side while it is rolling. (It may turn but it probably won't fall.) Ask the students if angular momentum is involved when the wheel is rolling. (Yes, it is.) Show the video at Resource Button C. Ask students if they think it would be really hard to change the angle of the wheel's rotational axis.

Invite volunteers to sit on a stool and duplicate David Heil's spinning bicycle wheel test from the video. Discuss their experiences as a class.

Activity 3

Explore (Approx. 25 min.)

Tell students they are going to explore gyroscopic action with a spinning phonograph record. (You can explain that it's an ancient technology that was replaced by CDs!) Have them use an old 33 rpm phonograph record to demonstrate the physics principle that is involved in gyroscopes. Tell students to tie a string around a toothpick, insert the toothpick through the hole in the record, and hold the string so that the record hangs above the floor. Have them swing the record gently. The record will flop around as it swings back and forth and changes its direction.

Tell students to spin the record parallel to the floor and start it swinging again. Have students record their observations.

This time, the record will stay parallel with the ground, seeming to float above the floor. Point out to the students that if the record were to tilt, its angular momentum would not change, but its axis of rotation would change direction. If it stays level, the record has become a gyroscope, and its constant direction is called "gyroscopic stability."

Evaluate

1. Explain why it is easier to balance a spinning basketball on a fingertip than a stationary basketball. (The gyroscopic action of the spinning ball makes it more stable and therefore easier to balance.)

2. Gyroscopes are used in airplanes as compasses. Knowing what you do about gyroscopes, why would this be so? (The axis of a spinning gyroscope can be set so that it always points in one direction—north, for example—no matter what direction the airplane is going.)

3. How are gyroscopic action and conservation of angular momentum alike? How are they different? (Alike: Both involve an object spinning around a rotational axis. Different: Gyroscopic action relates to the rotation axis remaining in a constant position. Conservation of angular momentum relates to how mass is distributed around the rotational axis.)

Try This

Explore toy gyroscopes. Try balancing a gyroscope on a fingertip or on a tightly stretched string. Then tie string to both ends of the axis of rotation of a spinning gyroscope and knot them together so that the gyroscope hangs freely beneath the point where the strings join. Hold the strings above the knot and note the direction of the hanging gyroscope's axis of rotation. Walk in any direction while holding the gyroscope, and observe the direction of that axis. It should not change, no matter what direction you walk. That is the principle on which the gyrocompass is based.

Discover precession. Balance a spinning gyroscope on a smooth, flat surface or on a gyroscope stand. Pay attention to the direction of its axis of rotation as it slows down. Notice that gravity does not make it topple directly. Instead, the axis tilts slightly and leans and moves in a circle, forming a cone shape.

GYROSCOPES

Activity Sheet 3

NAME _____ CLASS PERIOD _____

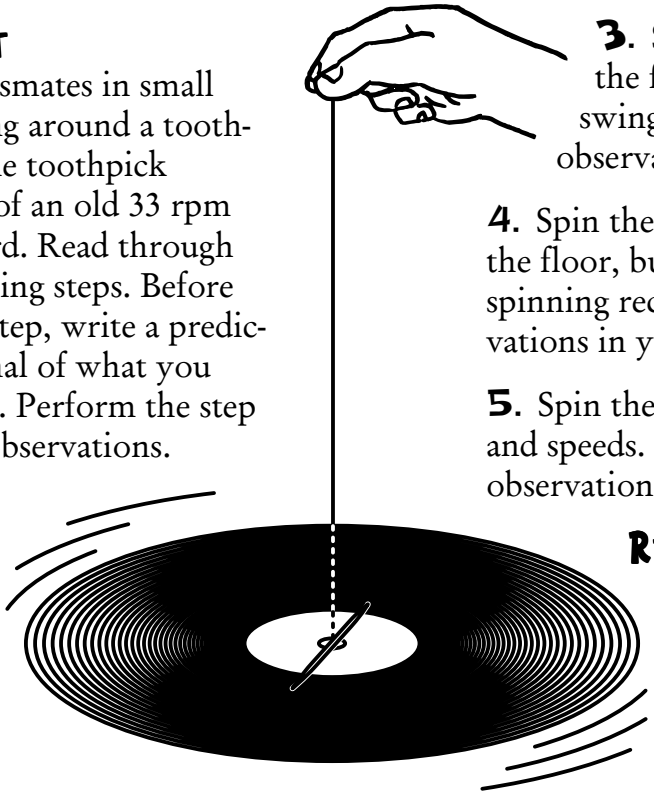
WHAT YOU'RE GOING TO DO

You're going to explore gyroscopic action and observe how it affects a spinning object.

HOW TO DO IT

1. Work with classmates in small groups. Tie a string around a toothpick, and insert the toothpick through the hole of an old 33 rpm phonograph record. Read through each of the following steps. Before performing each step, write a prediction in your journal of what you think will happen. Perform the step and record your observations.

2. Allow the record to hang above the floor. Swing the record gently. Write your observations in your journal.



3. Spin the record while it is parallel to the floor. Gently move the string in a swinging motion again. Write your observations in your journal.

4. Spin the record so that it is not parallel to the floor, but at a 45° angle. Again, swing the spinning record on the string. Write your observations in your journal.

5. Spin the record at several different angles and speeds. Swing it on the string. Record your observations.

RECORDING YOUR DATA

In your science journal record your predictions and observations for each step of this activity. Be sure to note anything that happened that was different from what you expected.

WHAT DID YOU FIND OUT?

What happened to the record when you spun it and let it swing?

Did the spinning record behave as you expected? Why or why not?

Did your predictions improve over the course of the activity? Why do you think this happened?

Compare your observations with other groups and discuss them as a class.

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Skimming the Surface

How are water skis different from other kinds of skis? How do water skis stay up on top of the water? Does the size of a water ski affect how fast the tow boat has to go? Can a person water-ski barefoot? How?

Themes and Concepts

- motions and forces
- action/reaction
- deflection of a fluid and fluid flow

National Science Education Content Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard B: Students should develop an understanding of motions and forces and transfer of energy.
Content Standard G: Students should develop an understanding of the nature of science.

Activities

1. ***Deflection Detection—Approx. 20 min. prep; 45 min. class time***
Why do water-skiers always start out with their skis pointing almost straight up in the air? Students calculate the relationship between the speed of the flow of water and the angle of the ski. They use a "deflecto-meter" and discover how the angle of the ski is critical to keeping a skier up. Students also explore how Newton's third law of motion applies to waterskiing.

2. ***Go Fly a Ski—Approx. 20 min. prep; 45 min. class time***
Do small skis have to move faster than large skis to stay up? Students find out for investigate the relationship between surface area and fluid velocity with "air skis." They learn that changing the surface area of a ski has a dramatic effect on how fast the water has to flow to keep a water-skier up.

3. ***Don't Be a Drag—Approx. 20 min. prep; 40 min. class time***
Why are water skis rounded at their ends? Is there a relationship between the shape of a ski and the way it flows through the water? Students construct model skis and, using a special liquid, determine how the stream-lined shape of a ski helps it go through the water.

More Information

Internet

Newton's Apple
http://www.ktca.org/newtons
(The official *Newton's Apple* web site with information about the show and a searchable database of science ideas and activities.)

International Water Ski Federation
http://www.iwsf.com/
(Home page of the International Water Ski Federation with links to other sites, as well as news on waterskiing events and tournaments.)

Global WaterSki Ventures
http://www.globalski.com/link.html
(A site that provides numerous links to sites about waterskiing, including the American Water Ski Association's site.)

Internet Search Words

water ski(s)
waterskiing
hydrodynamics

Waterskiing

Books and Articles

Duvall, C. and Crowell, N. *Camille Duvall's Instructional Guide to Waterskiing.* New York: Simon and Schuster, 1992. (The basics of how and why water skis work.)

Kistler, B. *Hit It! Your Complete Guide to Water Skiing.* Champaign, IL: Human Kinetics Publishers, Inc., 1988. (Great overview of the sport.)

Michel, M. "Waterskiing Without a Splash," *Sports Illustrated For Kids.* v. 7 no. 9 Sept. 1995, p 13. (Good story for kids about kids waterskiing.)

Community Resources

Waterskiing instructors, classes, or clubs

American Water Ski Association
799 Overlook Drive
Winterhaven, Fl 33884
(813) 324-4341

Background

Watching an expert water-skier is truly poetry in motion. Skimming over the surface of the water at speeds approaching 60 kilometers per hour (40 miles per hour), these champions seem to defy gravity as they fly over the water. Unlike snow skis that have solid ground to support them, water skis depend on the upward push of water to provide lift. Combining the buoyant effects of a boat moving across water with the fluid flow of a kite riding the air, water skis are a prime example of how different physical principles come together in a single sport.

The first person to successfully water-ski was Ralph Samuelson in 1922. He first tried a pair of old barrel staves, then standard snow skis. Samuelson's early attempts left him all wet, but they did lead him in the right direction. Discovering that he needed to displace a greater amount of water to stay up, he went to bigger and bigger skis. Finally, using a pair of pine boards that had a total surface area of more than one square meter (12 square feet), he was able to "ride the wake" and the sport of waterskiing was born.

The key to keeping water skis moving over the surface is a function of the amount of water flowing against the bottom of the ski as well as the speed of the skis. Just like a kite sailing on the wind, a water ski is lifted by the force of water pushing against it. The greater the volume of water pushing on the skis, the greater the lift. As the speed of the skier increases, so does the volume of water hitting the skis. The critical factor in controlling the amount of push is the angle of deflection. A skier usually starts out in the water with the skies almost vertical. This position means that when the boat begins to pull forward, the on-rushing water will hit the bottom of the ski straight on, producing a great deal of opposing force. Because the rope is pulling the skier forward, the two forces balance and the skis are lifted up on top of the water. As the speed of the skier increases, the angle between the ski and the water decreases until it is almost horizontal, or parallel, with the surface of the water.

As boat engines became more powerful and tow boats became faster, skiers soon realized that they didn't need as much surface area to keep them afloat. As a result, skis gradually became smaller and more aerodynamic. Rudders were added to help control turns and specialized shapes were created for different stunts. Pyramid skis, those used in ski shows by people building a human pyramid, are broad and flat. This allows the skis to distribute a large amount of weight over a lot of water surface. Many people ski on a single ski, called a slalom ski. It is wider and longer than normal skis and has a toe hold behind the normal foot binding to allow the rider to control the single ski.

The most experienced skiers can skim along the water using nothing but their feet. Called barefooting, this sport requires tow boats to move at speeds close to 60 kilometers per hour. Not only does barefooting take a lot of practice, but it requires courage and a whole lot of sole!

Video & Stills

Video Segments

Introduction

10:15 to 10:50—Dave Huddleston introduces the physics of waterskiing and asks, "How do people stand up on water?" (35 sec.)

Video Clip 1

10:50 to 12:18—With the help of physicist Amy Alving, SuChin Pak finds out if water-skiers float on the water. (1 min. 28 sec.)

Video Clip 2

12:18 to 14:54—SuChin Pak learns about the power of air and water and demonstrates Newton's third law with a boat paddle in moving water. (2 min. 36 sec.)

Video Clip 3

14:54 to 16:02—Amy Alving and SuChin Pak discuss how the size of a ski relates to the speed needed to keep it up—the bigger the ski, the slower you can go. (1 min. 8 sec.)

Video Clip 4

14:54 to 17:41—SuChin Pak finds out that the shape of a ski is as important as its size. (2 min. 47 sec.)

Additional Resources

Button A

Video: Newton's Lemon of an invention for walking on water

Button B

Diagram: Technical drawings of water skis

Button C

Table: A chart showing the relationship between a skier's weight and the size of water ski needed

Button D

Video: Newton's Lemon of a ski lift for water skiers

Unit Assessment Answer Key

The Unit Assessment on the following page covers the basic concepts presented in the *Newton's Apple* video segment and the Background section in this guide. The assessment does not require completing all of the activities. The Unit Assessment may be used as a pre- or post-test. However, students should view the complete *Newton's Apple* video before doing this assessment. There is additional assessment at the end of each activity.

Think about it.

1. Air pushes against a kite to keep it up in the air, and water pushes against a water ski to keep it up in the water. A difference is that once a kite is up, the air moves and the kite is relatively station ary; however, the water ski is pulled through the water, and the water is relatively stationary.
2. As the skis are pulled through the water, the water is deflected, pushing the water skis up.
3. The larger the water ski, the slower the speed that is needed.
4. The same principle is involved in keeping water skis up. However, because the surface area of bare feet is small, the barefoot skier must be pulled faster than the person wearing water skis.
5. When the skier slows or stops, the water stops moving and no longer supports the skis. Grav ity takes over and the skier sinks.

What would you say?

6. a 7. c 8. b 9. d 10. a

NEWTON'S APPLE Multimedia

Unit Assessment

What do you know about Waterskiing?

Write your answers in your journal or on another sheet of paper.

Think about it

1. How is waterskiing similar to flying a kite? How are they different?
2. What keeps a water-skier on top of the water?
3. How does the size of a water ski relate to the speed at which the boat must pull it?
4. What makes it possible for a person to waterski on bare feet?
5. Why does a skier sink when the boat slows or stops?

What would you say?

6. When a water-skier first starts off, in what position do the skis have to be?
   a. almost vertical
   b. almost horizontal
   c. flat on top of the water
   d. pointed out to the sides
7. What keeps a water-skier up on top of the water?
   a. gravity
   b. inertia
   c. deflection of the fast moving water hitting the ski
   d. buoyancy
8. Why are water skis rounded at the ends?
   a. to make them float better
   b. to reduce drag in the water
   c. to make them lighter
   d. to make them look like snow skis
9. Why are the skis used for pyramid tricks wider than normal water skis?
   a. The greater surface area makes them more stable.
   b. The greater surface area means that the skiers can get up at a slower speed.
   c. The greater surface area deflects more water.
   d. All of the above.
10. How would you correctly complete the following? The larger the ski, ———
    a. the more slowly the boat needs to pull.
    b. the less weight it can support.
    c. the faster the boat has to pull.
    d. the lighter it is.

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Activity 1

Deflection Detection

How do water-skiers stay up in the water? Is the angle of the ski in the water related to the speed of the skier? Are the forces that act on a water ski similar to those that act on a kite? What does Newton's third law have to do with waterskiing?

Getting Ready

Overview

What holds a water-skier up? Students learn how different forces work together to keep a water-skier on top of the water. Students discover that fluid deflection and forward motion keep a kite in the air and water-skiers on top of the water. Students test the relationship between fluid velocity and the degree of lift produced.

Objectives

After completing this activity, students will be able to—

- explain what keeps a water ski up and describe what forces are at work
- describe Newton's third law of motion and explain how it applies to waterskiing
- explain how a change in fluid velocity changes the degree of lift in a ski

Time Needed

Preparation: approximately 20 min.
Classroom: approximately 45 min.

Materials

For the teacher:

- wash bottle (squeeze bottle with spout) full of water
- dishpan or sink
- two 30-cm wooden rulers or wooden paint stirs
- 10-cm piece of string
- roll of waterproof (electric) tape
- 2 or 3 rolls of pennies
- towel
- a roll of plastic sandwich wrap

For each group of students:

- 10 cm x 20 cm piece of corrugated cardboard
- large paper clip
- protractor
- roll of cellophane tape
- 3-speed desk fan or portable hair dryer

Important Terms

action — A force pushing on an object.

deflect — To bend or turn aside from a straight course.

fluid — A liquid or gas capable of flowing from one place to another.

Newton's third law of motion — Where there is an action, there is an equal and opposite reaction.

Waterskiing

Here's How

Video Clip 1
10:50 to 12:18—With the help of physicist Amy Alving, SuChin Pak finds out if water-skiers float on the water. (1 min. 28 sec.)

Video Clip 2
12:18 to 14:54—SuChin Pak learns about the power of air and water and demonstrates Newton's third law with a boat paddle flat and moving water. (2 min. 36 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [10:15 to 10:50]. Find out what students already know about waterskiing. As a class, discuss the questions posed by Dave Huddleston.
- Students may want to try out their deflecto-meters with other sources of flowing motion, such as the air from a hair dryer or from the end of a straw. Allow them to test these and other devices to see how much force they produce. The amount of deflection measures the amount of lift produced by the flowing fluid. This force is generated by the total volume of fluid hitting the bottom of the cardboard over a given period of time.
- Have students think about the results they would get if they tried a wider or narrower piece of cardboard on the meter. How does this relate to the size of the ski and the speed of the tow boat?
- If it is appropriate, view the entire *Newton's Apple* video segment on waterskiing after completing the activity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 1 for each student.
- Review the information in the Background on page 24.
- Before starting the lesson, use waterproof tape to secure one end of the 10-cm string to the end of one of the wooden rulers so that the ruler hangs loosely from the string. Wrap two or three rolls of pennies in a sheet of plastic sandwich wrap and seal them with waterproof tape. Prepare the dishpan and wash bottle at the front of the room.

Engage (Approx. 15 minutes)

Ask students what they can tell you about waterskiing. Have they seen it on TV? Have they ever gone waterskiing themselves? Show Video Clip 1 [10:50 to 12:18], in which SuChin finds out if water-skiers float on the water. Ask students why water skis float. (The material they are made from is less dense than water.)

Hold up a wooden ruler or a paint stirrer. Explain that it will represent a ski. Ask students to predict what will happen when you put it into a pan of water. (It will float.) Tape two or three rolls of pennies or several washers to the top of the ruler and ask students what they think will happen when you add the weight of a "person" to this water ski. (The water ski will sink.) Ask students what keeps a water-skier on top of the water. Accept all answers. Show Video Clip 2 [12:18 to 14:54]. Ask students what a kite has to do with the way water skis stay up. Accept all answers.

Ask what air and water have in common. Accept all answers and then explain that both air and water are fluids. Fluids are gasses or liquids that can flow from one place to another. Water and air behave in some similar ways. Demonstrate this concept. Have one student suspend a ruler with a string and have another student blow on the ruler. What happens? (The ruler moves by deflecting the movement of the air.) Have the student hold the ruler over the pan of water and have the other student shoot a stream of water at the broad, flat side of the ruler, using the wash bottle. What happens to the ruler? (The force of the water is deflected by the ruler and the ruler moves.) The movement of both fluids caused the ruler to move.

Explain that this is Newton's third law of motion at play—for every action, there is an equal and opposite reaction. As the fluid exerts force on the ruler, the ruler exerts an opposite and equal force on the water. The result of these forces (and the fact that the skier is holding the tow rope) is that the ski rides over the water. In the video, SuChin asks, "What will happen when the boat stops?" Ask students for the answer. (Gravity and lift are no longer balanced. Gravity is stronger, so the skier sinks.)

Activity 1

Explore (Approx. 30 minutes)

Explain to the students that they are going to test this theory by building their own "deflecto-meter." Have students work in small groups.

Have the students straighten out a paper clip so that it has only one 90° bend in it. Have them place the paper clip through the small hole in the bottom center of a protractor and use a piece of cellophane tape to secure the paper clip to the back of the protractor. The long straight end of the wire protrudes out of and at a right angle to the front of the protractor.

Have the students push the straight end of the paper clip into the very top of the side of the piece of corrugated cardboard. The piece of cardboard should be able to swing back and forth freely on the paper clip. Tell the students to hold the protractor so that the cardboard hangs down parallel to the 0° line. The deflecto-meter is now ready for testing. Students can use the diagram on Activity Sheet 1 to help them build the deflecto-meter.

Have students hold the deflecto-meter by the protractor with the cardboard flap squarely in front of their mouths. Have them blow on it as hard as they can; the flap will move up. Have them blow on the flap again—first near the pin and then near the bottom. Have students observe where the greatest amount of deflection is produced.

Have students experiment with a fan to see how different quantities of air affect the angle of deflection. Have students measure the angle that the flap makes on the deflecto-meter and record it in their journals. Have them repeat the procedure with the fan on different settings. Students should make sure they hold the protractor in exactly the same place as before to eliminate any other variables.

Evaluate

1. Based on your observations, explain the relationship between the velocity of a moving fluid and the amount of lift produced by a water ski. (The faster the moving fluid, the more lift is produced.)

2. What two forces balance to keep the skier on top of the water? (Gravity is pulling the skier down and the force of the water against the ski is holding the skier up.)

3. The video relates waterskiing to kite flying. Based on your experiments, explain why you have to run with a kite to get it airborne. (You need the wind speed to create lift.)

Try This

Water skis aren't the only sports equipment that utilize the deflection of water and Newton's third law of motion. Find out how water skis compare to things like air boats, jet skis, and hydrofoils. Report your findings to the class.

Hydroplaning—skimming over the surface of water—is great for skis, but it can be dangerous for drivers on water-soaked roads. While hydroplaning involves different physics principles than waterskiing, it's a related phenomenon that most people have experienced. In what ways have tire manufacturers worked to minimize this problem? Research tire design as it relates to hydroplaning and report your findings to the class.

Try building your own water ski out of a small piece of wood and testing it in a nearby pond or pool using fishing weights to simulate the skier and a string to be the tow rope. How fast do you have to pull it to get it on top of the water with different amounts of weight?

DEFLECTION DETECTION

Activity Sheet 1

NAME _____ CLASS PERIOD _____

WHAT YOU'RE GOING TO DO

You're going to investigate the movement of an object that is deflecting a fluid against it.

HOW DO TO IT

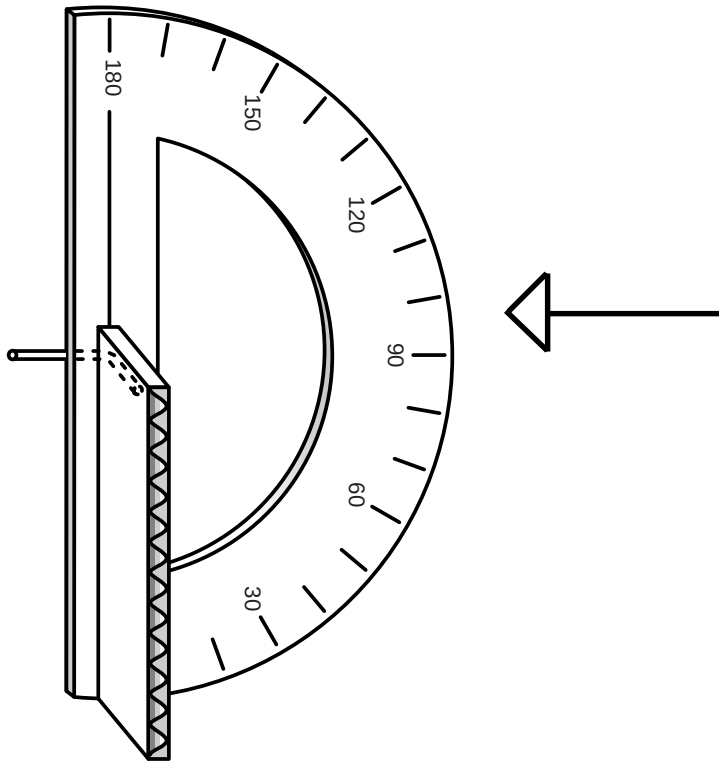
1. Work with several students and follow your teacher's instructions to assemble the deflecto-meter. The completed deflecto-meter should look similar to the one shown in the diagram.

2. After you construct your meter, explore how a fluid (air) striking the cardboard affects its angle. Use a 3-speed fan to provide the moving fluid.

3. Turn on the fan to the lowest setting and hold the deflecto-meter so that the bottom of the protractor is right in front of the fan. Measure the angle that the flap makes on the deflecto-meter and record it.

4. Repeat the procedure with the fan at medium and high speeds and the deflecto-meter in the same position.

5. Eliminate as many variables as possible, so that you test only the affect of the fluid on the cardboard.



RECORDING YOUR DATA

In your science journal, record your observations. Be sure to include fan speed and angle of deflection.

WHAT DID YOU FIND OUT?

What happened to the angle of deflection as you increased the speed of the fan?

Why was it important to keep the deflecto-meter in the exact same spot each time you made a measurement?

What would have to happen to the speed of the fan to get a reading of 90 on your deflecto-meter?

If a water-skier wanted to ride really high on the water, would the boat have to go fast or slow? Why?

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Activity 2

Go Fly a Ski

Does the size of a water ski affect how well it stays on top of the water? What is the relationship between the surface area of a ski and the speed the boat needs to pull it to get it up on the water? How can a person water-ski barefoot?

Getting Ready

Overview

Students build and test their own "air skis" and discover the relationship between the size of a ski and the velocity needed to hold it up. Students find that changing the surface area of a ski has a dramatic effect on how fast water has to flow to keep up a skier.

Objectives

After completing this activity students will be able to—

- explain the relationship between surface area and velocity needed for lifting skis
- explain the conditions necessary for an individual to ski barefoot
- calculate the volume of water pushing up on a ski over a given period of time
- explain the relationship between the surface area of a ski and the force needed to lift it up

Time Needed

Preparation: approximately 20 min.
Classroom: approximately 45 min.

Materials

For the teacher:

- large plastic spatula
- small plastic knife
- dishpan full of water

For each group of students:

- 3 pieces of typing paper (8.5" x 11")
- 3 pieces of kite string, each 1.5 meters long
- scissors
- cellophane tape
- metric ruler

Important Terms

deflect — To bend or turn aside from a straight course.

resistance — The amount of force pushing against something.

velocity — The speed something is going in a specific direction.

Waterskiing

Here's How

Video Clip 3
14:54 to 16:02—Amy Alving and SuChin Pak discuss how the size of a ski relates to the speed needed to keep it up—the bigger the ski, the slower you can go. (1 min. 8 sec.)

Preparation
- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 2 for each student.
- Review the Background information on page 24.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [10:15 to 10:50]. Find out what students already know about waterskiing. As a class, discuss the questions posed by Dave Huddleston.
- Unless you have a large classroom, you might want to do this activity outside or in a gymnasium or hallway so that students don't run into each other.
- You may have to remind some students how to calculate surface area.
- Some practice may be required for students to pull the air ski without spinning it. If the students use a steady velocity, the ski will work best. Paper clips may be attached to the air ski to provide added stability.
- Students may want to test a variety of different air ski designs to find out if other factors such as shape and curvature have any effect on the amount of lift they produce. Will the forces needed to lift an air ski change if stiffer material such as cardboard or foam core board is used? If time permits, have students experiment with other types of light materials to build the air skis.
- If it is appropriate, view the entire *Newton's Apple* video segment on waterskiing after completing the activity.

Engage (Approx. 15 min.)

In front of the class, have a student hold a spatula in one hand and a plastic knife in the other and pull them side by side through a dishpan full of water. Ask the student which offered more resistance—the knife or the spatula. (The spatula.) Why? (Because the spatula has a greater surface area, the water offers more resistance to it. The knife deflects less water.)

Ask the students to think about how changing the size of a ski might affect its performance in the water. Show Video Clip 2 [14:54 to 16:02]. Ask students which skier will have to be pulled faster, the one with small skis or the one with large skis. (The small skis because they deflect less water.)

The video tells how much faster a barefoot water-skier has to go to get the same lift that regular skis provide. Ask students for the answer. (The barefoot skier has to go almost twice as fast as regular skiers to get the same amount of lift out of the water.) Why? (Because the surface area of a foot bottom is much smaller than that of a ski and deflects much less water.)

Explore (Approx. 30 min.)

Have students work in groups of two or three. Explain that they are going to investigate how the surface area of a ski affects the speed needed to get the ski out of the water. Instead of using water and real skis, students are going to construct and test kite-like devices called "air skis."

Show students how to build "air skis." Fold up the long edges of an 8.5" x 11" sheet of paper to make two 1.5 cm-wide stabilizers. Use cellophane tape to attach string to one end of the ski as shown in the diagram on Activity Sheet 2.

Cut an 8.5" x 11" sheet of paper in half and use it to make a second air ski one half the width of the first one. Fold up the long edges to make two 1.5 cm-wide stabilizers, just as you did with the first ski. Attach the string to the ski in the same way that it was attached to the first ski.

Activity 2

Make a third air ski one half the width of the second one. Follow the same construction procedure.

Have students calculate the surface area for one side of each ski and record the information in their journals. Have students consider the following question: Based on the information they saw in the video, what is the relationship between speed and surface area?

Test the skis in a large open area. Have students hold the string, allowing the ski to rest on the ground behind them. The string should be held at about eye level of the student. Have students walk and then, if necessary, run until the ski is flying level with the moving student's head. Have students compare the speed needed to lift each ski (walking, jogging, running) and record it in their journals.

Evaluate

1. How does changing the surface area of a ski affect the speed needed to lift it out of the water? (The larger the surface area, the less speed is needed to lift the ski out of the water.)

2. Would it be better for beginning skiers to use short, narrow skis or long, wide skies? Why? (Long, wide skis would be better for beginners to learn the sport. The wider the skis are, the more stability the skier has and the less speed that is necessary to tow the skier.)

3. How is the design of a ski related to its specific use? Why would acrobatic skiers performing a pyramid trick want broad flat skis while those doing jumps and quick maneuvers require skis that are short and stubby? Explain how specific forces are controlled in each case. (Pyramid skiers need great stability, so wide skis are ideal because they provide more stability and do not require such high speeds. Skiers doing tricks and other quick maneuvers need short skis so that they can change the positions of the skis on the water quickly.

Try This

The video shows several varieties of skis, each one for a different purpose. Investigate different types of skies, including trick skies, boogie boards, pyramid skies, and slalom skies. Compare them to regular skies and decide how they make use of special designs to help control the forces of lift.

Is it ever possible for a skier to go faster than the tow boat? Certainly! When a boat goes into a tight turn, centrifugal force causes the skier to accelerate to speeds almost twice as fast as the boat. Use geometry to try to figure out how this happens.

GO FLY A SKI

Activity Sheet 2

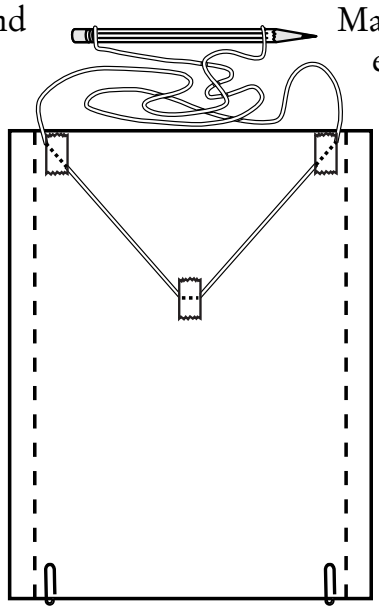
NAME _____ CLASS PERIOD _____

WHAT YOU'RE GOING TO DO

You're going to investigate the relationship between a ski's surface area and how much speed is needed to lift it.

HOW TO DO IT

1. Work with several classmates and make three "air skis" of different sizes according to your teacher's instructions.



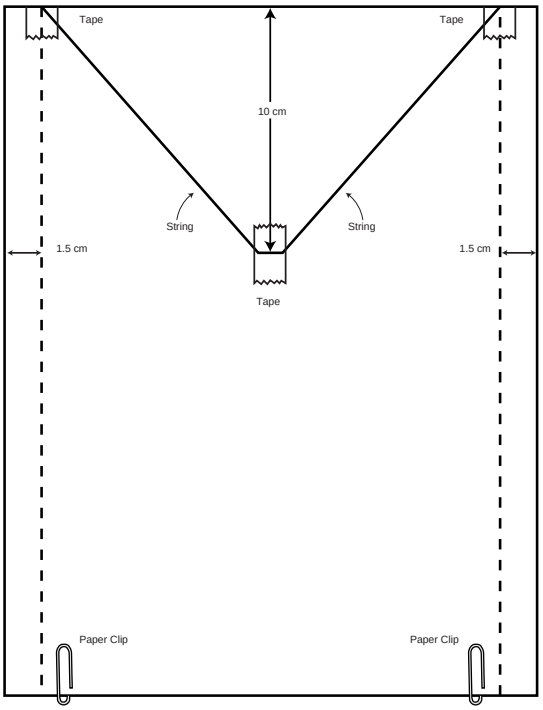
2. After building the air skis, measure their lengths and widths, calculate the surface area for each ski, and record it in your journal.

3. Test your air skis in a large open area. Have one member of your group place the air ski on the ground. They should hold the end of the string about eye level and pull the ski, like a kite. They should attempt to pull the ski fast enough to have it fly about head level.

4. Compare the speed needed to lift each ski and record it in your journal. Does the ski reach the level of your head at a walking speed, a jogging speed, or a running speed?

RECORDING YOUR DATA

Make a data table to record the size of each air ski and how much speed it took to get it in the air. Make notes about any other observations you may make during the experiment.



WHAT DID YOU FIND OUT?

Which ski needed the greatest speed to lift off the ground? Which took the least?

Did the small ski ever get fully airborne? If not, what do you think you would have to do to get it in the air?

How do you think the skis would have reacted if you added weight to them to simulate a rider?

Do you think there are limits to how big or small a water ski can be? Explain your answer.

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Activity 3

Don't Be a Drag

What characteristics must ski designers consider when making different types of water skis? What happens to the flow of water as a water ski first moves through the surface?

Getting Ready

Overview

What ski shapes move best through fluid? Students observe various ski designs and draw conclusions about the shapes of water skis and their ability to flow through a liquid. Using modeling clay and a special "rheoscopic fluid," students test different ski shapes and learn how shape controls the flow of the water around a ski.

Objectives

After completing this activity, students will be able to—

- explain how friction works on different shaped objects
- demonstrate how the shape of an object affects the resistance of a fluid flowing around it
- explain the difference between turbulent and laminar flow
- describe the difference in flow patterns created by an object moving through a liquid

Time Needed

Preparation: approximately 20 min.
Class Time: approximately 40 min.

Materials

For the teacher:

- football
- 3 large (9" x 12") metal or glass baking pans
- 3 quart containers of white Dove® brand dish-washing liquid
- large mixing bowl
- large spoon for mixing
- 3 small bottles of red or green food coloring
- approx. 1 gal. of water sponges and paper towels for clean up

For each student:

- chunk of non-water-soluble modeling clay about 5 cm x 5 cm x 5 cm in size
- piece of string about 10 cm long

Important Terms

drag — The horizontal part of the water force that the water exerts on the ski.

friction — The resistance to movement caused by the contact between two surfaces.

laminar flow — The movement of a fluid where the particles of the fluid move in distinct lines.

lift — The upward force that the water exerts on the ski.

rheoscopic fluid — A liquid with visibly suspended particles that allow direct observation of the liquid's movement and flow.

turbulent flow — The movement of a fluid where the particles of the fluid move in a random manner.

wake — The wave created by an object such as a boat or a water ski as it passes through the water.

Waterskiing

Here's How

Video Clip 4
14:54 to 17:41—SuChin Pak finds out that the shape of a ski is as important as its size. (2 min. 47 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [10:15 to 10:50]. Find out what students already know about waterskiing. As a class, discuss the questions posed by Dave Huddleston.
- The model skis that are being tested are designed to show the flow through the water before the skis get fully on top of the water. To see if the flow lines are the same or different on floating skis, make skis out of balsa wood and test them.
- Have students investigate how other items flow through a liquid. If time permits, let them try model cars, toy boats, or even common objects like pencils and rulers in the rheoscopic fluid. Discuss which shapes tend to cause the least amount of turbulence in the flow.
- You may wish to have students study the technical drawings of skis found at Resource Button B on the CD-ROM.
- If it is appropriate, view the entire *Newton's Apple* video segment on waterskiing after completing the activity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 3 for each student.
- Review the Background information on page 24.
- Make rheoscopic fluid by adding 1 quart of white Dove® dishwashing liquid to one quart of water and six to eight drops of food coloring. Mix thoroughly, and carefully pour the mix ture into one of the three baking pans. Repeat the procedure until you have three pans of fluid ready for use.

Engage (Approx. 10 minutes)

Ask students why the nose of an airplane is rounded and the body is streamlined. Discuss how the shape of the nose and body allows the plane to fly with the least amount of resistance.

Explain that a plane moving through the air is much like a water ski moving on top of the water. However, until it actually gets up on top of the water, a ski gets a great deal of resistance from the water. For this reason, skis are designed so they minimize water resistance. Show Video Clip 4 [14:54 to 17:41], in which SuChin learns about the shape of water skis. Have the students look for similarities and differences among the skis. Students should recognized that all three sets of skis are rounded at their ends. Two of the three are tapered from front to back.

Explore (Approx. 30 minutes)

Explain to the students that they are going to do an activity that will actually allow them to see why water skis are shaped the way they are. Using plastic modeling clay, they are going to design and construct several different types of skis and compare how much resistance the skis have when they flow through a liquid. To measure the resistance, students are going to use a special liquid called a rheoscopic fluid, which reveals flow patterns as an object moves through it.

Introduce the terms "turbulent flow" and "laminar flow," and if necessary, draw the two flow patterns on the board. (Turbulent flow is the flow of a fluid in random or chaotic fashion around an object. Laminar flow is the flow of a fluid in smooth or straight lines around an object.)

Activity 3

Explain to the students that their job is to design a ski that will create the least amount of turbulence in the fluid as the ski moves from one end of the pan to another. First, have them use the clay to make a model of a ski. Then have them draw the shape of their ski in their journals. Finally, have them test the ski in the fluid by placing it at one end of the pan and slowly pushing it through the fluid. After they move the ski through the water, have students draw diagrams of flow lines in their journals.

After they have built their first ski, have students modify its design and try it two or three more times. The ski that produces the smoothest flow lines in the fluid is the one that has the least amount of drag. When drag is minimized, the ski will flow very efficiently through the water. After testing several ski designs, have students discuss their results with classmates.

Evaluate

1. Which ski shapes seem to produce the least amount of turbulence in a fluid? (Skis that are curved or pointed in the front with a streamlined, tapered back.)

2. Reflecting on your experiment with the model skis, can you explain why fish such as sharks and sailfish are particularly fast swimmers? (They have the same type of streamlined body shape, so they create very little turbulence in the water around them as they swim.)

3. If a streamlined shape helps a ski cut down on turbulence, why aren't water skis made pointed in the front and broad in the back like a rocket or bullet? (For skis to get on top of the water, they must deflect the maximum amount of water in the front of the ski. As a result, the greater surface area must be toward the front of the ski.)

Try This

Water ski designers aren't the only engineers concerned with turbulent and laminar flow. Airplanes, racing cars, rockets, and boats all have to overcome frictional drag to move efficiently. Research how various industries test their products to see if they "go with the flow."

Visit a sporting goods store and compare different types of water skis. Are all skis created with the same basic shape, or do they have specific designs for different purposes? How do water skis compare to snow skis, boogie boards, surf boards, and kneeboards? How has the water ski evolved over time? Use the Internet to research the history of water skis. Modern skis are a far leap from the barrel staves that Ralph Samuelson first strapped onto his feet back in 1922. See what you can learn about the past and how some of these ideas may be coming back in the future.

Don't Be a Drag

Activity Sheet 3

Name_____ Class Period _____

What you're going to do

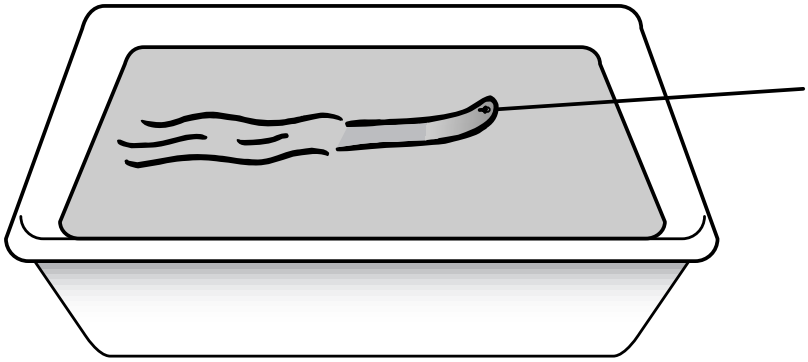
You're going to design a miniature water ski out of clay and use it to investigate the laminar flow of a liquid around the ski.

How to do it

1. Work with a small group of classmates. Make a model ski with the plastic modeling clay. Trace the shape of the ski in your journal and then test the ski by attaching a string to it and pulling it through the special rheoscopic liquid to see how much turbulence it creates. Observe the flow of liquid around the model ski and draw the flow around the ski you traced in your journal.

2. Try to reduce the flow lines to eliminate turbulence. Reshape your ski and trace it again. Pull it through the water again and observe the flow of the liquid. Draw flow lines again in your journal.

3. Continue experimenting with your ski design until you have eliminated as much turbulence as possible.



Record your data

Illustrate your observations in your science journal. Trace the shape of your model ski. Draw the flow lines of the liquid. Write down any other observations including information about how you modified your ski design.

What did you find out?

Which shape tends to make the most laminar flow through the liquid?

Which shape creates the most turbulence?

Compare your findings with those of other groups. Were your results similar? What might have caused any differences in results?

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